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Abstract

Emerging economies with inflation targets (IT) face a dilemma between fulfilling the theoretical conditions of "strict IT", which imply a fully flexible exchange rate, or applying a "flexible IT", which entails a de facto managed floating exchange rate with FX interventions to moderate exchange rate volatility. Using a panel data model for 37 countries we find that, although IT lead to higher exchange rate instability than alternative regimes, FX interventions in some IT countries have been more effective to lower volatility than in non-IT countries, which may justify the use of "flexible IT" by policymakers.

Keywords: Inflation targeting; Exchange rate volatility; Foreign exchange interventions; Emerging economies.

JEL classification: E31; E42; E52; E58; F31.

Resumen

Las economías emergentes con metas de inflación (MI) se enfrentan a un dilema entre cumplir las condiciones teóricas de una «MI estricta», lo que implica un tipo de cambio totalmente flexible, o seguir una gestión más activa de su moneda («MI flexible»), lo que supone implementar intervenciones cambiarias para moderar su volatilidad. Utilizando un modelo de datos de panel para 37 países, mostramos que, a pesar de que las MI implican una mayor inestabilidad del tipo de cambio que regímenes alternativos, las intervenciones realizadas por algunos países con MI han sido más eficaces para reducir la volatilidad que aquellas de países sin MI. Este resultado puede justificar la utilización de «MI flexibles» por parte de los bancos centrales.

Palabras claves: Metas de inflación, volatilidad del tipo de cambio, intervenciones cambiarias, economías emergentes.

Códigos JEL : E31; E42; E52; E58; F31.

1 Introduction

Since New Zealand adopted an inflation target (IT hereafter) in 1990, an increasing number of countries have implemented this monetary policy framework. According to IMF (2005) and Little and Romano (2009), after Israel adopted its IT in 1997, 18 emerging countries (EMEs onwards) have changed their exchange rate regime (from fixed to floating) and their nominal anchor (from exchange rate to inflation). See Table 1 for a summary of IT adoption dates in EMEs. Although the effectiveness of IT to lower the inflation level and volatility still remains controversial,[1] this framework has been more durable than other monetary policy strategies (Mihov and Rose, 2008). One of the main reasons for this is that IT countries have benefited from the credibility gains from explicitly announcing the target, which helped to anchor and lower inflation expectations (Mishkin and Schmidt-Hebbel, 2007).[2]

A flexible nominal exchange rate constitutes, at least from a theoretical standpoint, a requirement for a well functioning full-fledged IT regime (Mishkin and Savastano, 2001). Its rationale is based on the policy dilemma of the "impossibility of the Holy Trinity", as in a context of capital mobility, an independent monetary policy cannot be combined with a fixed exchange rate or a peg to another currency through interventions in the foreign exchange markets (also known as forex or FX interventions); see Obstfeld et al. (2005). Some economists state that one of the costs of IT is precisely the higher volatility of exchange rates as a result of the floating exchange rate regime, which can entail negative effects of particular relevance for EMEs given their greater financial and real vulnerabilities (Cavoli, 2009). In fact, this is the basis of the "fear of floating" (Calvo and Reinhart, 2002), which is a phenomenon mostly associated to EMEs.[3] Accordingly,

[1] See Ball and Sheridan (2005) or Brito and Bystedt (2010) for some empirical evidence against the positive role of IT in developed and emerging countries, respectively.

[2] This effect is even stronger in EMEs, as their initial credibility is lower than that of developed countries (Gonçalves and Salles, 2008).

[3] According to Cavoli (2009), the main reasons to justify the "fear of floating" are: (i) trade contraction —higher exchange rate volatility will discourage other countries to engage trade—; (ii) a higher pass-through from exchange rate to domestic prices in EMEs than in developed countries; and, (iii) balance sheet effects provoked by currency mismatches (liability dollarization).

during economic booms EMEs also experience "fear of appreciation" given their concerns for their loss of competitiveness (Levy-Yeyati and Sturzenegger, 2007).

Thus, exchange rate monitoring under IT poses some challenges for EMEs that differ from those in advanced economies. This might justify their more active role of the exchange rate policies—particularly in those countries where the exchange rate has previously played a key role as nominal anchor—despite the theoretical reservations about it. Consequently, in practice, EMEs with IT generally have less flexible exchange rate arrangements, intervene more frequently in foreign exchange markets than their advanced economy counterparts and have a greater response to real exchange rate movements (see Aizenmann et al., 2008, and Chang, 2008).[4]

This adaptive way of implementing IT has been called "flexible IT" and it has generated an intense debate about its validity and viability in EMEs, compared with "strict or pure IT", where the exchange rate does not enter in the reaction function of central banks.[5] That is, implicitly there is a policy dilemma between fulfilling the theoretical requirements of IT and strictly follow it, or applying a "flexible IT", in the sense of using FX interventions to smoothen the exchange rate volatility.

To this respect, there are different views in the literature. On the one hand, some authors like Bernanke et al. (1999) hold that attending to IT and reacting to the exchange rate are mutually exclusive as FX interventions could confuse the public about the priorities of the central bank, which distorts expectations. On the other hand, less strict authors argue that central banks might interfere with the exchange rate volatility. For instance, according to Cordero (2009), FX interventions are fully justified, as far as EMEs need to maintain stable and competitive real exchange rates. In fact, following Taylor (2000), some authors include the exchange rate in the policy reaction function arguing that it helps to mitigate the impact of shocks, by dampening exchange rate volatility

[4] In contrast to EMEs, the most common reason to perform FX interventions in IT advanced economies is to correct an exchange rate misalignment (Stone et al., 2009). In EMEs, there are other reasons to intervene, apart from moderating the exchange rate volatility (for instance, to influence on the exchange rate or to accumulate reserves).

[5] The term "flexible", as defined in Svensson (2010), refers to IT central banks that look, not only for price stability, but also consider other variables, such as the output gap or the exchange rate.

(Kirnasova et al., 2006; Cavoli, 2008).

Other papers reach halfway conclusions about the role of exchange rates in IT regimes from a more theoretical point of view. For instance, Stone et al. (2009) show that it depends on the structure of the economy, the nature of the shocks, and the way in which the exchange rate enters the policy rule. In the same line, Parrado (2004) finds that the adoption of flexible or managed exchange rates in a small open economy under IT depends on the nature and the sources of the shocks to the economy. Thus, the social loss is much higher under "flexible IT" than under "strict IT" for real and external shocks, while for nominal shocks the opposite holds. On the contrary, Yilmazkuday (2007) concludes with a calibrated model for Turkey that the welfare loss function is minimized under "flexible IT" for all the types of shocks. Finally, Roger et al. (2009) use a DSGE model to show that financially vulnerable EMEs are especially likely to benefit from some exchange rate smoothing given the perverse impact of exchange rate movements on activity.

In line with this debate, the main objective of our paper is to analyze empirically the relationship between IT, FX interventions and the exchange rate volatility. That is, we try to answer if there is any difference in terms of exchange rate volatility between the use of FX interventions in IT and non-IT countries. In other words, we want to analyze if the "fear of floating" and "fear of appreciating" behavior of some central banks may justify halfway policies between the fixed and fully floating, such as the "flexible IT"—which, in practice, is the most frequent way of EMEs to implement IT—.

Our study of the link between these three variables is based on a panel data model for 37 IT and non-IT EMEs from the first quarter of 1995 to the first quarter of 2010. Note that we cover the last financial crisis, whose effects on the relationship between IT adoption, FX interventions and exchange rate volatilities have not been analyzed in detail yet.[6] This crisis constitutes a natural experiment to test these links in turbulent periods (Habermeier et al. 2009), as the relatively more important role of the exchange rate policy in EMEs with IT than in developed ones became clear.[7] Thus, once we analyze the panel for the whole sample period, we also replicate our analysis for the time previous

[6]Among the few exceptions, see de Carvalho (2010).

[7]The tensions following the onset of the crisis were heightened by inflation pressures—nearly all EMEs with IT overshot their targets in 2008—, great exchange rate volatility, and financial stress.

to the onset of the financial crisis and the subsequent sub-sample. We date the beginning of the crisis on 2008:Q3.

We conclude that, although IT leads to higher exchange rate volatility than alternative regimes, the FX interventions of some IT countries, mainly in Latin America, have been more effective to lower the exchange rate volatility than those performed in non-IT countries, especially after the onset of the crisis. Thus, our results support the implementation of "flexible IT" by policymakers, as FX interventions under IT seem to be even more effective than those of non-IT countries in mitigating the exchange rate volatility. This outcome represents an additional argument in favor of IT, which have demonstrated to be sustainable during the crisis.[8]

The paper is organized as follows. After the introduction, Section 2 briefly displays the literature and Section 3 describes the data set, including the three main variables of the analysis—exchange rate volatility, FX interventions and a dummy variable that captures the fact of having an IT—. Then, Section 4 presents the methodology that will be used to analyze the panel data set. In Section 5, we report the main empirical findings. Finally, Section 6 concludes the paper.

2 Overview of the empirical literature

Previous empirical contributions on the analysis of the exchange rate volatility, IT adoption and FX interventions were mostly based on case studies for specific countries. For instance, Domaç and Mendoza (2004) analyze this link for two IT countries—namely, Mexico and Turkey—and conclude that negative FX interventions (foreign exchange sales) decreased their exchange rate volatility, whereas Guimarães and Karacadag (2004), on the contrary, consider that these interventions had a limited effect on volatility.[9] For Brazil, Minella et al. (2003) highlight the importance of transparency of interventions to avoid a credibility deterioration of monetary policy as a result of misunderstandings about the policy objective. Geršl and Holub (2006) and Kamil (2008) analyze the role of FX inter-

[8] In fact, no EME suspended IT after the financial crisis and only two countries adjusted their range.

[9] These two papers consider asymmetric effects, that is, a different effect of positive or negative interventions on the exchange rate volatility.

ventions in two other IT countries, the Czech Republic and Colombia, respectively, and conclude that occasional interventions may be useful to stabilize the currency, although they are less effective when there is no consistency between monetary and exchange rate policy goals.

There are some empirical papers for a wide sample of EMEs that separately analyze two of our three main variables, namely, exchange rate volatility and IT, or the former variable and FX interventions. On the one hand, the literature on the effect of IT on the exchange rate volatility is not conclusive. Edwards (2007) studies if the exchange rate volatility is different in IT and non-IT countries and concludes that the volatility increases with IT as a result of their flexible exchange rate regime, but after controlling for this variable this link disappears. De Gregorio et al. (2005) find the same evidence for Chile. By contrast, Rose (2007) studies a panel dataset and finds that, as a result of IT credibility gains, IT deliver the best outcomes in terms of lower exchange rate volatility, higher output growth and lower inflation than alternative regimes.

On the other hand, the empirical literature on the link between FX interventions and exchange rate volatility, without considering the monetary regime, is not quite developed either. Most of these contributions fit GARCH models for specific countries (Domínguez, 1998, and Edison et al., 2006 analyze developed countries). Finally, IMF (2007) analyzes five Asian managed-floating countries from 2000 to 2007 and finds limited evidence on interventions dampening the exchange rate volatility.

Our paper contributes to the previous literature in at least three directions. First, we analyze empirically the effect of FX interventions on the exchange rate volatility of IT and non-IT EMEs. To our knowledge, this is the first empirical application that combines the three variables for a panel of EMEs, and not for case studies on individual countries. Second, in our setting, interventions can be asymmetric, in the sense of allowing a different impact of positive and negative interventions (foreign exchange purchases or sales), which is also a novel approach in a panel data framework. Finally, we also analyze the period of the recent global crisis, which has not been much studied in this setting yet.

3 Data and explanatory variables

We perform a panel data analysis to test the implications in terms of exchange rate volatility of FX interventions in IT countries. Our sample consists of 37 countries: we compare the group of 18 EMEs that have already adopted IT (IMF, 2005, and Little and Romano, 2009) and a control group of 19 non-targeting countries—see Appendix A for the complete country list—. In the control group we explicitly exclude countries with a fixed exchange rate with the dollar or any other hard currency (like the euro) in the whole sample period as their exchange rate volatility is zero.[10] We also exclude fully dollarized countries as they relinquish any possibility of having an autonomous exchange rate policy.[11] Finally, for the sake of comparability of both groups and following Lin and Ye (2009), our control group includes non-targeting EMEs that have a real GDP per capita and population at least as large as that of the poorest and smallest IT country, which guarantees their economic relevance. With this selection criteria our control group represents all emerging regions and covers a broad range of exchange rate regimes.

The sample runs from 1995:Q1 to 2010:Q1. The choice of the initial period rested on avoiding the potential problems of extreme movements in the exchange rates of many EMEs until the mid-nineties, especially in Latin America, under a context of hyperinflation. We have also excluded some countries, such as Serbia, due to problems of data availability at the beginning of the sample period. If possible, we have obtained missing observations at the beginning or at the end of of the sample with national sources, so that our panel is strongly balanced.

To measure the exchange rate volatility, σ_{ERt}, we calculate the quarterly standard deviation of daily returns. The percent return of the nominal exchange rate against the dollar for a country i follows this expression,

$$r_t = 100 \times (\Delta \log E_t) \tag{1}$$

where, $\forall t = 1, ..., T$, E_t is the bilateral nominal exchange rate in t and Δ is the difference

[10] There are some relevant currencies, like the Chinese yuan, that are in our control group although China had a currency peg during most of the sample period. However, given its economic relevance and as its currency peg does not cover all the sample period, we include China in our sample.

[11] We use Carranza et al. (2009) to identify fully dollarized countries or with fixed exchange rates.

operator (a positive r_t is a depreciation of the local currency against the dollar).[12] In the paper we use the nominal bilateral exchange rate against the dollar as it has advantages in terms of data availability and it is a rather intuitive choice as the dollar is used in most EMEs to borrow in (Carranza et al., 2009).[13] Note that this proxy is not necessarily the best volatility approximation.[14] Finally, our measure is less smooth than that proposed in Rose (2007), who uses the standard deviation over a four year window of monthly data.

Regarding IT, we build a binary dummy variable for each EME, IT_t, that is one after formal IT adoption and zero otherwise (see Rose, 2007). To disentangle the formal IT adoption date, we follow IMF (2005) and Little and Romano (2009)—see Table 1—. Note that, given that dating IT adoption is not straightforward, we consider that of the formal or explicit IT adoption for all countries, which may differ from the date of the IT announcement—when the IT could be combined with alternative objectives, such as the exchange rate or a money aggregate—.

We approximate FX interventions with ΔRES, where RES is the ratio of foreign exchange reserves over GDP.[15] This variable approximates the pace of reserve accumulation -or losses- as well as FX interventions of a country (a positive value indicates a net purchase of foreign currency). However, one weakness of ΔRES as proxy of FX interventions is that we cannot distinguish if the reserve variation is associated to a real intervention in the exchange rate markets or to alternative reasons.[16]

In our analysis we are also interested in possible asymmetric effects of FX interventions. That is, we want to know if there is a different effect on the exchange rate volatility

[12] Following Harvey et al. (1994), we subtract the mean of $\Delta \log E_t$ to guarantee zero mean returns.

[13] Nominal effective exchange rates are available by JP Morgan only for a small number of EMEs, whereas IFS data—available at a monthly frequency—, which were used by Edwards (2007) and Rose (2007), also suffer from this limitation.

[14] For instance, the volatility of a fixed exchange rate is zero, but if the exchange rate collapses as a result of persistent misalignments their volatility jumps.

[15] To measure RES we tried to minimize the distortional effects of local currency depreciation on nominal GDP denominated in dollars. We have also tried to clean the effect of IMF disbursements and repayments on RES. Nevertheless, this process is not straightforward, so that we have just considered the two biggest repayments of our sample (Brazil (2005:Q4) and Argentina (2006:Q1)).

[16] One option that is out of the scope of this paper would be to estimate an unobservable threshold to disentangle those reserve variations that are truly linked to interventions (Kim and Sheen, 2002).

in the case of an accumulation or a loss of reserves (positive or negative FX interventions). For this type of analysis we use for all countries and periods the interaction of ΔRES_{it} with a dummy variable, D_{it}, that is 1 if the stock of reserves over GDP decreases and zero otherwise. That is, $\forall i = 1, ..., N$, and $\forall t = 1, ..., T$,

$$\begin{aligned} D_t &= 1, \qquad \text{if} \quad \Delta RES_t < 0 \\ D_t &= 0, \qquad \text{otherwise.} \end{aligned} \tag{2}$$

Table 2 reports some summary statistics for IT and non-IT countries of σ_{ER}, RES, the FX interventions as proxied by ΔRES, and the negative interventions, $D \times \Delta RES$. We analyze the full sample and the period before and after the crisis. Regarding σ_{ER}, the mean volatility is higher in IT countries, especially in after the crisis, whereas non-IT countries exhibit a higher coefficient of variation than IT countries, which means that volatility jumps in these economies are greater. With respect to the stock of reserves, the mean RES in the pre-crisis period is similar in both types of countries, but after the crisis it is 0.29 in non-IT countries and 0.19 in IT countries. That is, once the more severe phase of the crisis was over, non-IT countries strongly accumulated reserves, whereas in IT countries this mean is rather stable. Regarding ΔRES, it is surprising that, on average, IT and not-IT countries implement a similar volume of FX interventions in the full sample, despite the requirements of a "strict IT". However, contrary to IT countries, in the post-crisis period non-IT countries had on average negative FX interventions. These statistics of ΔRES_t mask negative interventions, as defined by $D \times \Delta RES$. In the post-crisis period IT countries did sell foreign reserves, violating the principles of "strict IT".

Finally, for the robustness of our results, we also use five control variables (see Appendix B for more details). Specifically, we employ (1) the degree of trade openness, as higher openness increases the reaction to real exchange rate shocks (Cavoli, 2008); (2) current account (as percentage of GDP); (3) the natural logarithm of population, (4) the real GDP per capita and (5) one financial variable that approximates global risk aversion, proxied by the implied volatility of the S&P index (VIX).[17] Table 3 shows the pairwise correlations of the five control variables and the main variables of our analysis.

[17] In previous versions we also considered other control variables, which we have omitted due to its lack of significance or multicolinearity problems. This is the case of the exchange rate regime as classified by

4 Empirical model and econometric issues

4.1 The model

We fit nine panel data models that we denote as M1 to M9, which are based on combinations between IT, RES, ΔRES and D. The estimation procedure is based on pooled OLS with time dummies. We fit the models for the full sample, and also for two subsamples: From 1995:Q1 to 2008:Q2, to characterize the period previous to the turmoil, and from 2008:Q3 to 2010:Q1, to analyze the impact of the recent financial crisis. Models M1 to M3 are built out of this expression,

$$\sigma_{ERit} = \beta_0 + \beta_1 \sigma_{ERit-1} + \beta_2 IT_{it} + \beta_3 RES_{it} + \beta_4 RES_{it} \times IT_{it} + \sum_j \delta_j X_{jit} + \varepsilon_{it}, \qquad (3)$$

where, $\forall i = 1, ..., N$, and $\forall t = 1, ..., T$, the exchange rate volatility, σ_{ERit}, is a function of σ_{ERit-1}—to capture volatility persistence—, IT_{it}, RES_{it}, the interaction between both variables and the set of five controls, X_{it}.

In models M4 and M5, we increase the number of drivers in (3) with $D_{it} \times RES_{it}$ and $IT_{it} \times D_{it} \times RES_{it}$, that will provide information about the possible different impact of reserve variations on the exchange rate volatility under an accumulation of reserves, where $D_{it} = 0$, or a loss, where $D_{it} = 1$.

Finally, in models from M6 to M9 we include ΔRES_{it}, which approximates the pace of reserve accumulation -or losses- of country i. In particular, M6 follows this expression

$$\sigma_{ERit} = \beta_0 + \beta_1 \sigma_{ERit-1} + \beta_2 IT_{it} + \beta_3 \Delta RES_{it} + \sum_j \delta_j X_{jit} + \varepsilon_{it}, \qquad (4)$$

whereas in models M7 to M9 we extend (4) by also regressing the interaction of ΔRES_{it} with IT_{it} and/or D_{it}. For the sake of clarity we omit RES_{it} in specifications from M6 to M9. The combination of these variables lead us to analyze if in IT countries the effect of FX interventions in the exchange rate volatility is different to that in non-IT countries. Moreover, we can also study if this effect is asymmetric, that is, if the impact of the purchases or sales of reserves on the volatility is different and to check whether there

Ilzetzki et al. (2008) given its severe multicollinearity problems with IT and the volatility of commodities prices (as measured by the CRB index).

has been a punishment for these interventions under an IT regime in the form of higher exchange rate volatility than in non-IT countries.

Finally, we also estimate the panel model using a six-quarter rolling window.[18] This allows us to analyze the evolution of total effects of positive and negative interventions on IT and non-IT countries along the sample period. These time-varying coefficients let us know, for instance, if these links have changed during the last crisis.

4.2 Statistical inference

As mentioned, we distinguish between (i) countries with IT or not; and, (ii) countries that have lost or accumulated reserves (D=1 or D=0, respectively). Their combination lead to four possible total effects of FX interventions on σ_{ER}, so that we can use their coefficients to perform statistical inference. We calculate these four possible total effects from the sum of the relevant coefficients. Namely, (1) the estimate for ΔRES indicates the impact of positive FX interventions performed by a non-IT country, whereas (2) the coefficient of $\Delta RES + (D \times \Delta RES)$ indicates that of negative interventions in non-IT countries; (3) $\Delta RES + (IT \times \Delta RES)$ denotes the effect of positive interventions in IT countries, and, finally (4) $\Delta RES + (IT \times \Delta RES) + (D \times \Delta RES) + (IT \times D \times \Delta RES)$ stands for the impact of negative interventions in IT countries.

Statistical inference is useful to analyze more formally the significance of the effects of interventions on the exchange rate volatility depending on the IT adoption or on the intervention sign. To this end we propose two Wald-type tests. First, we analyze if the impact of negative interventions held on IT countries is different than that of non-IT countries. To confirm this hypothesis, we test this null,

$$H_0 : \beta_{IT \times \Delta RES} + \beta_{IT \times D \times \Delta RES} = 0, \quad (5)$$

where β_j denotes the coefficient of the explanatory variable j. If interventions performed by IT counties have a different effect on σ_{ER}, the null in (5) will be rejected. Second, we study if the effect of interventions in IT countries is significatively asymmetric, that is, if negative interventions have a different effect on σ_{ER} than that of positive interventions,

[18] The length of the rolling window has been chosen so as to coincide with the post-crisis sample size.

by testing this null hypothesis,

$$H_0 : \beta_{D\times\Delta RES} + \beta_{IT\times D\times\Delta RES} = 0 \qquad (6)$$

If interventions are asymmetric, this null will be rejected. In Section 5 we interpret some of these statistics.

4.3 Econometric issues

As mentioned, our estimation procedure is based on pooled OLS with time dummies. Our estimation approach entails several problems. First, we cannot use country fixed effect dummies, as IT is time-invariant in certain subperiods, so that country fixed effects would translate to the intercept. However, the set of control variables allows us to control for the unobserved heterogeneity across countries.

Another difficulty in the analysis is the potential for endogeneity biases as a result of reverse causality and omitted variables. Although the Generalized Method of Moments (GMM) estimator of Arellano and Bond (1991) is well-known to tackle endogeneity issues in a dynamic panel data framework, we must discard this procedure, as GMM is only consistent in short panels ($N >> T$), but this is not our case ($T = 61$ and $N = 37$).

As regards reverse causality, it could be a concern when analyzing the link between our three main variables. For instance, with respect to the relationship between exchange rate volatility and FX interventions, one can interpret that FX interventions help to manage market uncertainty but, on the other hand, it can be inferred that FX interventions might simply coincide with periods of higher uncertainty, which is precisely the reason to intervene. To further analyze this relation, we have also performed several Hausman-Wu tests (Hausman, 1983; Wu, 1973). According to these tests, we can consider ΔRES as exogenous to σ_{ER} in t, as all tests failed to reject the null of exogeneity (these tests are available upon request), so that ΔRES would be independent of the errors in the models.[19]

[19] As an additional robustness test of our pooled OLS estimates, we have also tried to address the possible reverse causality biases by also performing instrumental variables (IV) estimators using lagged FX interventions as instruments. We chose these lagged variables as instruments of ΔRES as they can be regarded as exogenous to the exchange rate volatility and are correlated with ΔRES. However, the

On the other hand, the causality relation between the exchange rate volatility and IT adoption seems clearer. Edwards (2007) or Rose (2007) study the effect on the exchange rate volatility of following an IT. However, Gonçalves and Carvalho (2008) analyze the opposite causality relation and show that the volatility of the real exchange rate (as a proxy of adverse shocks) is not statistically significant to explain the probability of IT adoption. Regarding possible omitted variable bias, the set of control variables helps to identify them.

5 Empirical results

5.1 The role of IT adoption and RES

Table 4 reports the estimates for models from M1 to M9 for the whole sample period—upper panel—, as well as for the pre-crisis and post-crisis period—central panel and lower panel, respectively—.

Is IT associated with higher exchange rate volatility? As a first result, IT seems to be related to higher σ_{ER}, given the positive and significant coefficients of IT in Table 4. This link is robust across specifications and it is even higher and more significant after the crisis, when this relation exacerbated (as also reported in Table 2). This result is in line with De Gregorio et al. (2005) or Edwards (2007), and contrary to Rose (2007), who concludes that IT does not come at the expense of higher exchange rate volatility. This positive association could be mostly explained by the own exchange rate regime. However, we explicitly exclude this control variable in the model as it is highly correlated with IT, which leads to serious multicollinearity problems.[20]

As shown in Table 4 there is a negative link between RES and σ_{ER} for the whole sample and the coefficients, around -0.4 , are quite robust across specifications. It can

correlation between ΔRES_t and ΔRES_{t-1} is relatively low. Also note that in the main results of the IV estimates the effect of σ_{ERt-1} and IT dominates, and prevents identifying the effects of interventions.

[20] To prove this a priori assumption, we have added as control variable the exchange rate regime as measured by the monthly coarse classification of Ilzetzki et al. (2008). This index labels countries from 1 to 6 in increasing order according to their degree of exchange rate flexibility. As expected, this control leads to non-significant IT coefficients and multicollinearity.

be interpreted that higher stocks of reserves coincide with more stable exchange rates. The negative relation is even higher in IT countries, as shown by the estimates of $IT \times RES$ from M3 to M5. This might be a consequence of the higher flexibility of their exchange rates, which exacerbates the favorable effect of reserve accumulation on σ_{ER}. This negative association cannot be identified after the crisis in non-IT countries, as the estimates for IT countries—usually higher than in non-IT countries—dominate the relation between RES and σ_{ER}.

5.2 The effect of FX interventions on the volatility

As mentioned, we also distinguish periods of appreciatory pressures (when the central bank buys reserves) from those of depreciatory pressures (when the central bank sells reserves), with D as defined in (2). As shown by the estimates of $IT \times RES \times D$ in M4 and M5 of Table 4, the negative link between RES and σ_{ER} seems to be different under appreciatory or depreciatory pressures for the whole sample and for the pre-crisis period in IT countries. That is, under depreciatory pressures, those IT countries with a higher buffer of foreign reserves have a lower exchange rate volatility.

Models from M6 to M9 in Table 4 report the results that directly involve ΔRES. The analysis of the impact of FX interventions on the exchange rate volatility is particularly relevant. As already stated, EMEs intervene very frequently, even under IT, as a common way to stabilize the exchange rate. We have three main results. First, FX interventions seem to lower the exchange rate volatility only in IT countries, whereas, surprisingly, in non-IT countries interventions are not significant. This result is robust across subsamples. In fact, we clearly reject the null hypothesis in (5), so that negative interventions in IT and non-IT countries have a different impact on the volatility.[21]

Second, regarding the sign of interventions, the sales of reserves tend to be significant in IT countries in both subsamples (the estimates of $IT \times D \times \Delta RES$ are negative and significant).[22] After the crisis positive interventions are also significant. However,

[21] The p-value associated with the joint Wald-type test for M9 is 0.008.

[22] Under a negative intervention, $IT \times D \times \Delta RES$ is negative, so that a positive coefficient implies a negative effect on σ_{ER}.

both effects are asymmetric in the sense that the impact of negative interventions is significatively different than that of positive interventions, as confirmed by the test of the null in (6).[23]

Finally, in IT countries, the total effect of lower reserves on the exchange rate volatility increases after the crisis, as shown by the sum of coefficients, $\Delta RES + (IT \times \Delta RES) + (D \times \Delta RES) + (IT \times D \times \Delta RES)$.

We complete this analysis with the study of the time-varying effect of negative and positive FX interventions on the exchange rate volatility in IT and non-IT countries. Figure 1 and Figure 2 represent the coefficients of the total effects of negative and positive interventions, respectively, obtained after fitting again the panel using a six-quarter rolling window. According to Figure 1, in non-IT countries the effect of negative interventions is negative (that is, sales of foreign reserves are associated even with greater exchange rate volatility) or close to zero at the end of the sample, although this effect is not significant.[24] Meanwhile, since 2005 in IT countries this link is increasingly positive and significant. Thus, Figure 1 confirms previous results in the sense that negative interventions seem to be useful to lower the exchange rate volatility, especially in the last part of the sample, whereas in non-IT countries these interventions have a limited role in shaping the volatility.

On the other hand, Figure 2, that represents the coefficients of the rolling window estimates for IT and non-IT countries under positive interventions, illustrates that in non-IT countries this effect is around zero along the sample. Nevertheless, in IT countries the total coefficient becomes negative, especially since 2008.[25] Again, these conclusions confirm our previous results.

All in all, our results support the role of FX interventions in IT countries, especially during crisis periods. Our outcomes also express some doubts about the effectiveness of

[23]We reject the null hypothesis of symmetric effects on the exchange rate volatility of positive and negative interventions at 10%, and the p-value of the test for M9 is 0.081.

[24]We have also calculated the t-values of the sum of coefficients with the delta method. These results are available upon request.

[25]The total effect of positive FX interventions is non significant for non-IT countries, whereas in IT countries they are significant since 2008.

FX interventions performed by non-IT countries to reduce the exchange rate volatility. Finally, we do not identify either any significant effect of interventions of IT countries in tranquil periods under appreciatory pressures.

5.3 Analysis by region

Finally, we also perform the same analysis by region, namely Latin America, Emerging Asia and Eastern Europe. Tables 5 to 7 report these estimates, respectively.

Regarding Latin America, the main result in Table 5 is that $IT \times \Delta RES$ and $IT \times D \times \Delta RES$ are significant in the post-crisis period. That is, FX interventions carried out by IT countries during the crisis were associated with lower σ_{ER}, which is again a result favorable to the use of FX interventions during crisis times in IT countries. On the other hand, the positive link between IT and σ_{ER} is identified only in the post-crisis period. One possible interpretation might be that before the crisis σ_{ER} has extreme values in some non-IT and IT countries—before IT adoption—corresponding to different domestic crisis episodes (for instance, Argentine, Mexico or Brazil). Finally, in Latin America the negative relation between RES and σ_{ER} is stronger in IT countries, but only in the pre-crisis period, when a considerable amount of reserves was accumulated.

According to the estimates for Emerging Asia in Table 6, IT loses its significance in the post-crisis period. Besides, RES is only significant in the post-crisis period and its coefficient is higher than for the whole country sample and ΔRES plays no role neither for IT nor non-IT countries. Finally, regarding Eastern Europe, the positive link between IT and σ_{ER} is only identified in the pre-crisis period, as reported in Table 7. However, we do not find any significant relation between RES and the exchange rate volatility and, as in Emerging Asia, ΔRES is not significant in any specification, as far as these estimates seem to be dominated by the dynamics of σ_{ERt-1}. All in all, the full sample results for the post-crisis period regarding ΔRES reported in Table 4 seem to be dominated by certain counties from our Latin American sample.

6 Conclusions

In this paper we have analyzed empirically the link between exchange rate volatility, IT and FX interventions. As far as in practice most central banks with IT have tried to conduct monetary policy with some form of price stabilization objective and also manage movements in its currency ("flexible IT"), these FX interventions might have implications for monetary policy and the use of policy rules. In this sense, "flexible IT" imply a departure from the corner solutions derived from the "impossibility Holy Trinity" of fixed exchange rates, independent monetary policy and perfect capital mobility and have several broad implications for the role of the exchange rate in IT countries.

To analyze this question we estimate a panel data model for 37 IT and non-IT EMEs. We study the impact of IT adoption and foreign reserve movements—that we roughly interpret as FX interventions—on the exchange rate volatility. We also perform this analysis for the period previous to the onset of the financial crisis and the subsequent sub-sample. This exercise is useful to disentangle if IT does make a difference in terms of the impact of FX interventions on the exchange rate volatility.

We confirm that exchange rates are more volatile under IT than under other regimes in EMEs, which is against the results in Rose (2007). However, we also show that FX interventions in IT countries do play a useful role in containing the exchange rate volatility, especially the negative ones (sales of foreign reserves). This outcome is particularly significant after the onset of the recent financial crisis in Latin America. Surprisingly, this role of negative FX interventions in the moderation of the exchange rate volatility is not identified in non-IT countries.

All in all, we support the view that there is some scope for EMEs that have adopted IT to interpret the implementation of their IT mechanisms with certain degree of flexibility. Thus, "flexible IT" regimes are not only sustainable, but also FX interventions performed under this scheme are even more effective than those of non-IT countries in mitigating extreme volatility periods. However, there is still some room for future research to analyze if these episodes of heavy FX interventions have not undermined the credibility of these central banks.

Appendix A: Country list

Inflation targeters		**Non-inflation targeters**	
Brazil	Peru	Albania	Guatemala
Colombia	Philippines	Algeria	India
Czech Republic	Poland	Argentina	Jamaica
Chile	Romania	Cambodia	Malaysia
Ghana	Slovak Republic	China	Morocco
Hungary	South Africa	Costa Rica	Russia
Indonesia	South Korea	Croatia	Singapore
Israel	Thailand	Dominican Republic	Ukraine
Mexico	Turkey	Egypt	Uruguay
			Vietnam

Appendix B: Definition of variables and data sources

- IT: Dummy variable that is one if the country had a formal IT in that quarter. Source: IMF (2005) and Little and Romano (2009).
- Reserves, RES_{it}: Foreign exchange reserves over nominal GDP in US dollars. Source: International Financial Statistics (IMF).
- Openness: Exports plus imports as a percentage of GDP. Source: International Financial Statistics (IMF), Datastream and national sources.
- Current account: Current account as a percentage of GDP. Source: International Financial Statistics (IMF), Datastream and national sources.
- Population: Logarithm of population (thousand persons). Source: World Economic Outlook (IMF).
- GDP per capita: Gross domestic product based on purchasing-power-parity (PPP) per capita. Source: World Economic Outlook (IMF).
- VIX: Implicit volatility of the S&P 500 index. Source: Datastream.

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Figure 1: Six-quarter rolling window estimates. Total effect of negative FX interventions $(D = 1)$ on the exchange rate volatility in non-IT (left), and IT countries (right).

Figure 2: Six-quarter rolling window estimates. Total effect of positive FX interventions $(D = 0)$ on the exchange rate volatility in non-IT (left), and IT countries (right).

Table 1: Date of adoption of the formal IT in emerging markets and current target. Sources: IMF (2005), Little and Romano (2009) and national sources.

	IT adoption date	**Point target (%)**	**Target range (%)**
Israel	Jun. 1997	None	$1-3$
Czech Republic	Jan. 1998	3.0	$\pm$ 1.0
South Korea	Apr. 1998	None	$3.5-4.0$
Poland	Jan. 1999	2.5	$\pm$ 1.0
Brazil	Jun. 1999	4.5	$\pm$ 2.0
Chile	Sep. 1999	3.0	$\pm$ 1.0
Colombia	Sep. 1999	None	$2-4$
South Africa	Feb. 2000	None	$3-6$
Thailand	May. 2000	None	$0-3.5$
Mexico	Jan. 2001	3.0	$\pm$ 1.0
Hungary	Jul. 2001	3.0	$\pm$ 1.0
Peru	Jan. 2002	2.0	$\pm$ 1.0
Philippines	Jan. 2002	None	$4-5$
Slovak Republic	Jan. 2005	None	None
Indonesia	Jul. 2005	5.0	$\pm$ 1.0
Romania	Aug. 2005	3.5	$\pm$ 1.0
Turkey	Jan. 2006	7.5	$\pm$ 2.0
Ghana	May. 2007	None	$6-8$

Source: IMF(2005) and Little and Romano (2009); current IT point target and range target also obtained from national sources. Slovak Republic became non-IT in January 2009 after Euro adoption.

Table 2: Summary statistics of σ_{ER}, RES, ΔRES and $D \times \Delta RES$ for a sample of 37 countries (quarterly data, based on nominal exchange rates against the dollar). We consider 2008:Q3 as the date of the beginning of the crisis.

		Mean		CV		Max		Min	
		IT	Non-IT	IT	Non-IT	IT	Non-IT	IT	Non-IT
σ_{ER}	Full sample	0.643	0.507	0.676	1.289	4.507	8.637	0.041	0.000
	Pre crisis	0.565	0.501	0.561	1.331	2.818	8.637	0.041	0.000
	After crisis	0.971	0.575	0.676	0.861	4.507	4.251	0.141	0.000
RES	Full sample	0.167	0.186	0.444	0.984	0.505	1.026	0.036	0.006
	Pre crisis	0.164	0.177	0.420	0.987	0.415	1.026	0.036	0.006
	After crisis	0.187	0.285	0.502	0.830	0.505	1.018	0.082	0.041
ΔRES	Full sample	0.002	0.002	7.311	6.916	0.086	0.080	−0.043	−0.101
	Pre crisis	0.001	0.003	11.521	5.312	0.086	0.080	−0.043	−0.085
	After crisis	0.005	−0.003	3.550	−7.871	0.061	0.069	−0.028	−0.101
$D \times \Delta RES$	Full sample	−0.003	−0.004	−1.833	−2.162	0.000	0.000	−0.043	−0.101
	Pre crisis	−0.003	−0.003	−1.848	−2.148	0.000	0.000	−0.043	−0.085
	After crisis	−0.004	−0.010	−1.743	−1.639	0.000	0.000	−0.028	−0.101

Summary statistics of the exchange rate volatility based on nominal exchange rates against the dollar (σ_{ER}), the stock of foreign reserves (RES); FX interventions (ΔRES) and negative FX interventions ($D \times \Delta RES$). CV: coefficient of variation (standard deviation / mean); Max: Maximum; Min: Minimum.

Table 3: Correlation matrix

	σ_{ER}	IT	RES	ΔRES	$D \times \Delta RES$	Current account	Openness	Population	GDP per capita	VIX
σ_{ER}	1									
IT	0.10*	1								
RES	−0.14*	−0.05*	1							
ΔRES	0.00	−0.01	0.12*	1						
$D \times \Delta RES$	−0.05*	0.05*	−0.18*	0.74*	1					
Current account	−0.06*	−0.08*	0.65*	0.15*	−0.05*	1				
Openness	0.03	0.01	0.11*	−0.04	−0.02	−0.10*	1			
Population	−0.07*	0.08*	−0.14*	0.04	0.09*	0.12*	−0.20*	1		
GDP per capita	0.05*	0.36*	0.39*	−0.01	−0.10*	0.24*	0.16*	−0.38*	1	
VIX	0.25*	0.05*	0.02	−0.03	−0.09*	−0.02	−0.02	0.01	0.05*	1

* significant pairwise correlation at 5%.

Table 4: OLS coefficient estimates from regressions of exchange rate volatility on IT dummy and foreign reserves.

	M1	M2	M3	M4	M5	M6	M7	M8	M9
Total sample									
$\sigma_{ER,t-1}$	0.53***	0.52***	0.51***	0.51***	0.51***	0.53***	0.53***	0.53***	0.53***
IT	0.07**	0.05	0.15**	0.15**	0.15**	0.07**	0.07**	0.07**	0.10***
RES		−0.45***	−0.40***	−0.39**	−0.39**				
$IT \times RES$			−0.56**	−0.56**	−0.54**				
$D \times RES$				−0.01	0.01				
$IT \times D \times RES$					−0.31*				
ΔRES						−0.57	−0.45	0.70	1.70
$IT \times \Delta RES$							−0.58		−3.32
$D \times \Delta RES$								−3.03	−4.85
$IT \times D \times \Delta RES$									9.30**
N	2048	2039	2039	2039	2039	2036	2036	2036	2036
R^2	0.39	0.40	0.40	0.40	0.40	0.39	0.39	0.39	0.39
Pre-crisis									
$\sigma_{ER,t-1}$	0.52***	0.51***	0.51***	0.51***	0.51***	0.53***	0.53***	0.53***	0.52***
IT	0.06*	0.04	0.12*	0.12*	0.13*	0.06*	0.06*	0.07*	0.09**
RES		−0.48***	−0.44**	−0.44**	−0.44**				
$IT \times RES$			−0.48*	−0.49*	−0.46*				
$D \times RES$				0.01	0.02				
$IT \times D \times RES$					−0.35**				
ΔRES						−0.68	−0.82	1.11	1.61
$IT \times \Delta RES$							0.80		−1.96
$D \times \Delta RES$								−4.49	−6.05
$IT \times D \times \Delta RES$									8.99**
N	1819	1810	1810	1810	1810	1807	1807	1807	1807
R^2	0.35	0.36	0.36	0.36	0.36	0.35	0.35	0.36	0.36
Post-crisis									
$\sigma_{ER,t-1}$	0.51***	0.51***	0.48***	0.48***	0.48***	0.51***	0.52***	0.52***	0.50***
IT	0.11	0.10	0.31**	0.32**	0.32**	0.13*	0.14*	0.12*	0.20**
RES		−0.15	−0.02	−0.05	−0.04				
$IT \times RES$			−0.98**	−0.97**	−0.95*				
$D \times RES$				0.08	0.10				
$IT \times D \times RES$					−0.28				
ΔRES						−1.53	−0.38	−2.50	2.19
$IT \times \Delta RES$							−3.49		−7.41*
$D \times \Delta RES$								1.95	−4.05
$IT \times D \times \Delta RES$									15.82*
N	229	229	229	229	229	229	229	229	229
R^2	0.57	0.57	0.58	0.58	0.58	0.57	0.57	0.57	0.58

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; Pooled OLS estimations. Dependent variable: Exchange rate volatility (proxied by the quarterly standard deviation of daily r_t—log difference of the bilateral exchange rate against the dollar—; IT : binary dummy, IT=1 if countries have adopted IT; RES: Foreign reserves over GDP; D: binary dummy, $D = 1$ if $\Delta RES < 0$; Controls not reported but included: (1) Current account as percentage of GDP; (2) Trade openness; (3) Log of population; (4) GDP per capita; (5) VIX index; Intercept and time controls included but not reported; We consider 2008:Q3 as the start of the financial crisis.

Table 5: OLS coefficient estimates from regressions of exchange rate volatility on IT dummy and foreign reserves. Latin America.

	Latin America: Total sample								
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**
$\sigma_{ER,t-1}$	0.50***	0.42***	0.42***	0.42***	0.42***	0.50***	0.50***	0.50***	0.49***
IT	0.03	0.11	0.04	0.04	0.04	0.02	0.02	0.03	0.08
RES		−2.40***	−2.60***	−2.59***	−2.63***				
$IT \times RES$			0.56	0.57	0.69				
$D \times RES$				−0.05	0.10				
$IT \times D \times RES$					−0.88				
ΔRES						−3.86	−4.94*	−1.64	−0.11
$IT \times \Delta RES$							4.45		−4.38
$D \times \Delta RES$								−4.97	−10.78
$IT \times D \times \Delta RES$									22.96*
N	591	591	591	591	591	59	591	591	591
R^2	0.40	0.43	0.43	0.43	0.43	0.40	0.40	0.40	0.41

	Latin America: Pre-crisis								
$\sigma_{ER,t-1}$	0.48***	0.41***	0.41***	0.41***	0.41***	0.48***	0.48***	0.48***	0.48***
IT	−0.01	0.07	−0.02	−0.02	−0.01	−0.01	−0.02	−0.01	0.02
RES		−2.42***	−2.66***	−2.66***	−2.69***				
$IT \times RES$			0.71	0.72	0.75				
$D \times RES$				−0.02	0.08				
$IT \times D \times RES$					−0.60				
ΔRES						−4.82*	−5.60*	−1.71	−1.07
$IT \times \Delta RES$							3.52		−1.99
$D \times \Delta RES$								−7.20	−10.32
$IT \times D \times \Delta RES$									15.00
N	524	524	524	524	524	524	524	524	524
R^2	0.37	0.41	0.41	0.41	0.41	0.38	0.38	0.38	0.38

	Latin America: Post-crisis								
$\sigma_{ER,t-1}$	0.44**	0.31*	0.24	0.20	0.21	0.43**	0.42**	0.43**	0.42**
IT	0.19	0.37**	0.91***	1.02***	0.95***	0.19	0.20	0.21	0.34*
RES		−2.64**	−0.46	−0.70	−0.83				
$IT \times RES$			−3.60**	−4.04**	−3.28*				
$D \times RES$				0.82	1.16				
$IT \times D \times RES$					−1.44				
ΔRES						3.21	1.34	−2.82	7.92
$IT \times \Delta RES$							4.20		−18.72*
$D \times \Delta RES$								9.95	−12.66
$IT \times D \times \Delta RES$									45.73*
N	67	67	67	67	67	67	67	67	67
R^2	0.61	0.66	0.68	0.69	0.70	0.61	0.62	0.62	0.67

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; Pooled OLS estimations. Dependent variable: Exchange rate volatility (proxied by the quarterly standard deviation of daily r_t—log difference of the bilateral exchange rate against the dollar—; IT : binary dummy, IT=1 if countries have adopted IT; RES: Foreign reserves over GDP; D: binary dummy, $D = 1$ if $\Delta RES < 0$; Controls not reported but included: (1) Current account as percentage of GDP; (2) Trade openness; (3) Log of population; (4) GDP per capita; (5) VIX index; Intercept and time controls included but not reported; We consider 2008:Q3 as the start of the financial crisis.

Table 6: OLS coefficient estimates from regressions of exchange rate volatility on IT dummy and foreign reserves. Emerging Asia.

	Asia: Total sample								
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**
$\sigma_{ER,t-1}$	0.65^{***}	0.62^{***}	0.62^{***}	0.62^{***}	0.62^{***}	0.66^{***}	0.66^{***}	0.66^{***}	0.66^{***}
IT	-0.17^{*}	-0.24^{*}	-0.36^{*}	-0.36^{*}	-0.36^{*}	-0.16^{*}	-0.14	-0.16^{*}	-0.14
RES		-1.12^{*}	-1.18^{*}	-1.18^{*}	-1.18^{*}				
$IT \times RES$			0.50	0.49	0.49				
$D \times RES$				-0.01	-0.01				
$IT \times D \times RES$					0.21				
ΔRES						-2.38	-1.66	-2.96	-1.64
$IT \times \Delta RES$							-3.91		-4.25
$D \times \Delta RES$								1.44	-0.05
$IT \times D \times \Delta RES$									2.15
N	415	415	415	415	415	415	415	415	415
R^2	0.64	0.65	0.65	0.65	0.65	0.64	0.65	0.64	0.65

	Asia: Pre-crisis								
$\sigma_{ER,t-1}$	0.65^{***}	0.63^{***}	0.63^{***}	0.63^{***}	0.63^{***}	0.65^{***}	0.65^{***}	0.66^{***}	0.66^{***}
IT	-0.18^{*}	-0.24^{*}	-0.45^{*}	-0.45^{*}	-0.45^{*}	-0.18^{*}	-0.17^{*}	-0.18^{*}	-0.18^{*}
RES		-1.00	-1.01	-1.02	-1.02				
$IT \times RES$			0.95	0.94	0.94				
$D \times RES$				-0.03	-0.04				
$IT \times D \times RES$					0.21				
ΔRES						-1.71	-1.58	-2.37	-2.47
$IT \times \Delta RES$							-0.87		0.09
$D \times \Delta RES$								1.61	2.11
$IT \times D \times \Delta RES$									-3.45
N	367	367	367	367	367	367	367	367	367
R^2	0.64	0.65	0.65	0.65	0.65	0.64	0.64	0.64	0.64

	Asia: Post-crisis								
$\sigma_{ER,t-1}$	0.50^{**}	0.22^{*}	0.22^{*}	0.22	0.21	0.47^{***}	0.55^{**}	0.47^{**}	0.52^{**}
IT	-0.19	-0.34	-0.40	-0.39	-0.36	-0.17	0.01	-0.17	0.11
RES		-2.46^{*}	-2.55^{*}	-2.54^{*}	-2.49				
$IT \times RES$			0.12	0.11	0.06				
$D \times RES$				0.02	0.02				
$IT \times D \times RES$					-0.38				
ΔRES						-6.37	-3.72	-6.78	-2.34
$IT \times \Delta RES$							-8.71		-11.45
$D \times \Delta RES$								1.03	-1.13
$IT \times D \times \Delta RES$									26.23
N	48	48	48	48	48	48	48	48	48
R^2	0.66	0.73	0.73	0.73	0.73	0.70	0.73	0.70	0.75

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; Pooled OLS estimations. Dependent variable: Exchange rate volatility (proxied by the quarterly standard deviation of daily r_t—log difference of the bilateral exchange rate against the dollar—; IT : binary dummy, IT=1 if countries have adopted IT; RES: Foreign reserves over GDP; D: binary dummy, $D = 1$ if $\Delta RES < 0$; Controls not reported but included: (1) Current account as percentage of GDP; (2) Trade openness; (3) Log of population; (4) GDP per capita; (5) VIX index; Intercept and time controls included but not reported; We consider 2008:Q3 as the start of the financial crisis.

Table 7: OLS coefficient estimates from regressions of exchange rate volatility on IT dummy and foreign reserves. Eastern Europe.

	Eastern Europe: Total sample								
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**
$\sigma_{ER,t-1}$	0.36^{***}	0.36^{***}	0.36^{***}	0.36^{***}	0.36^{***}	0.37^{***}	0.37^{***}	0.37^{***}	0.37^{***}
IT	0.13^{**}	0.11^{*}	0.10	0.11	0.12	0.12^{**}	0.12^{**}	0.13^{**}	0.12^{**}
RES		−0.64	−0.65	−0.70	−0.70				
$IT \times RES$			0.04	−0.04	−0.06				
$D \times RES$				0.23	0.27				
$IT \times D \times RES$					−0.24				
ΔRES						−1.46	−2.04	−1.11	−2.04
$IT \times \Delta RES$							1.73		2.00
$D \times \Delta RES$								−0.87	−0.01
$IT \times D \times \Delta RES$									−1.41
N	604	604	604	604	604	604	604	604	604
R^2	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36

	Eastern Europe: Pre-crisis								
$\sigma_{ER,t-1}$	0.36^{***}	0.35^{***}	0.35^{***}	0.35^{***}	0.35^{***}	0.36^{***}	0.36^{***}	0.36^{***}	0.36^{***}
IT	0.12^{**}	0.09	0.09	0.11	0.13	0.11^{*}	0.11^{*}	0.11^{**}	0.11^{*}
RES		−0.82	−0.82	−0.87	−0.88				
$IT \times RES$			0.04	−0.11	−0.16				
$D \times RES$				0.27	0.32				
$IT \times D \times RES$					−0.33				
ΔRES						−1.92	−2.91	−1.17	−2.03
$IT \times \Delta RES$							3.45		2.92
$D \times \Delta RES$								−2.01	−2.31
$IT \times D \times \Delta RES$									1.90
N	532	532	532	532	532	532	532	532	532
R^2	0.26	0.26	0.26	0.27	0.27	0.26	0.26	0.26	0.26

	Eastern Europe: Post-crisis								
$\sigma_{ER,t-1}$	0.35^{***}	0.34^{***}	0.31^{*}	0.31^{*}	0.31^{*}	0.35^{***}	0.36^{***}	0.35^{**}	0.35^{**}
IT	0.19	0.16	−0.80	−0.91	−0.94	0.19	0.19	0.17	0.14
RES		−0.58	−4.04	−4.30	−4.31				
$IT \times RES$			4.23	4.66	4.66				
$D \times RES$				−0.32	−0.45				
$IT \times D \times RES$					0.66				
ΔRES						0.11	1.68	−1.36	−0.71
$IT \times \Delta RES$							−3.30		−0.59
$D \times \Delta RES$								3.31	3.89
$IT \times D \times \Delta RES$									−9.31
N	72	72	72	72	72	72	72	72	72
R^2	0.53	0.53	0.54	0.54	0.54	0.53	0.53	0.53	0.53

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; Pooled OLS estimations. Dependent variable: Exchange rate volatility (proxied by the quarterly standard deviation of daily r_t—log difference of the bilateral exchange rate against the dollar—; IT : binary dummy, IT=1 if countries have adopted IT; RES: Foreign reserves over GDP; D: binary dummy, $D = 1$ if $\Delta RES < 0$; Controls not reported but included: (1) Current account as percentage of GDP; (2) Trade openness; (3) Log of population; (4) GDP per capita; (5) VIX index; Intercept and time controls included but not reported; We consider 2008:Q3 as the start of the financial crisis.

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